Journal of Sustainable Development Studies
ISSN 2201-4268
Volume 5, Number 1, 2014, 29-39

Material Flow Analysis (MFA) for Waste Management in Olive Oil Industries sector in South Europe

Spyridon Achinas

School of Forest Science and Resource Management, Technical University of Munich, Hans-Carl-von- Carlowitz-Platz 2, 85354 Freising, Germany

Abstract. The olive oil waste management was always one of the biggest problems in agricultural and environmental sector. Besides, everyone can observe that the olive oil industries produce every year more that 10 million tons of waste including wastewaters and solid waste (leaves, dry pomace). It is given attention to the challenges which exist for waste treatment (there are different cases) and of course following the different legal frameworks at European and National level.

Cause of the increase of the amount of olive oil mills waste every year, it's necessary to increase the awareness of the olive oil mills stakeholders encouraging them in sustainable olive mill waste (OMW) management, always with cooperation of the public services and research centers for positive solutions. The OMW management is becoming a critical issue for the sustainability of olive oil industry, because of the increasing quantities generated, the public environmental awareness and stricter environmental laws. This paper provides a view of perspectives for waste management in olive oil sector for the main oil producing countries, Greece, Spain, Italy and Portugal using the material flow analysis (MFA) approach as a tool.

Keywords: olive oil mills, dry pomace, leaves, wastewater, material flow analysis

1. Introduction

To achieve a sustainable development for South Europe regions it is essential to manage the waste production and to leave unpolluted ecosystems to future generations. Officials and planners aiming at sustainable development have to adapt the management objectives of resources and waste to the regional and European requirements. The method, MFA, studies the fluxes of resources used and transformed as they flow through an olive mill, through a single process or via a combination of various processes. It analyzes the flux of different materials through a defined space and within a certain time (Lehmann, 2010). In industrialized countries, MFA proved to be a suitable instrument for early recognition of environmental problems and development of solutions to these problems. It is possible to collect and combine data from the markets with data from waste management, in order to observe the variation in different regions (Brunner and Rechberger, 2005).

The problems of waste management, and the opportunities to promote sustainable material flows, depend on the level of development. In the most obvious sense, prompt collection and disposal of waste is required for sanitation; wastes must flow outward every day. Although there are some developments in the implementations, there is no specific legal regulation about the waste management in the industry. The oil producing municipalities regulate autonomously the waste management, based on the experience from the past years or whether it is participating to an environmental program or not (Ackerman, 2005).

Table 1. Characteristics of the present situation in South European countries

Spain	• it has forbidden by law from 1982 the river disposal of olive mills wastewater • future replacement of the more water consumptive 3PCS pressing system by the 2PCS to produce less wastewater
Italy	• over 5,000 olive mills that operate using the traditional pressing system • the only country with a special legislation for the disposal and recycling of the wastes
Greece	• almost 3000 olive mills, the 70% of them being 3PCS • olive mill owners hesitate to upgrade to the 2PCS cause of the complex mixture of OMW for extraction • following the EU direction all olive mills have to change to 2PCS

This paper provides a sustainable concept for waste management in olive oil mills sector for the main oil producing countries of Southern Europe using as a tool the material flow approach for the different types of olive oil mills.

MFA supplies an understanding behavior about the connection of inputs of organic material with the outputs of the milled material and waste treatment processes. Those waste referred to in this paper comprises the streams of solid waste and wastewater. Focus is placed on the waste fluxes in olive oil industry. Economic, political and social issues are not dealt with in this paper. The management of oil production sector results in the following basic questions:

- Which are the key procedures in organic material and nutrient fluxes and waste management processes of olive oil mills in South Europe?
- How much is the nutrient demand of agriculture coming from OMW?
- To what extent can pollution to water and soil be reduced by collecting and treating olive mills waste?

2. System approach

2.1. Method

The development of a material flux analysis starts with a system analysis. The system implies the supply, consumption and disposal sector.

a) Which are the subsystems/processes in the system?

b) Which are the most important flows between the subsystems/processes?

c) Which are the most important and output flow into the system?

In MFA, materials or material mixtures with functions valued by man are defined as "goods". The term "process" denotes the transport, transformation or storage of materials and goods (Brunner and Rechberger, 2005). In system analysis it is convenient to link goods and processes. Each good has one origin and one destination process. An output of a process is named as an export good and can be an input to another process in the system as an import good. This is called material flux. As a result of this, the processes are linked through the flow of goods (Belevi, 2002).

A material flow analysis comprises:

1) A system analysis comprising goods and processes
2) Determination of the mass fluxes of all the goods per unit of time
3) Determination of the concentrations of the selected elements in these goods
4) Calculation of the mass and element fluxes from the mass fluxes of goods and element concentrations in these goods
5) Interpretation and presentation of the results

The processes themselves can be viewed as black boxes (Brunner and Rechberger, 2005).

2.2. Potential for sustainable waste management

Olive oil production is carried out in "mills." Batch (press) and continuous processes are the main methods used in olive oil production. Depending on the pressing method used in continuous operation, three technologies are recognized: traditional pressing, two- and three-phase processes. These processes mainly differ in the process water requirements. The olive oil extraction procedure contains many different parameters, the major being whether the olive mill uses traditional pressing system, 2PCS or 3PCS. The 2PCS as mentioned above produces a watery cake, a mixture of solid and liquid wastes. The other two extraction systems, namely the traditional pressing system and the 3PCS, separate the solids from the liquid wastes (Azbar et al., 2004).

In three-phase systems (3PCS) process water is added and three phases (oil, wastewater, solid wastes in the form of an olive cake) are produced. The 3PCS system practically produces liquid and solid residues in the form of a sludge. This sludge, which is also called pomace, is more difficult to handle (due to the higher humidity – it is "stickier") but quite profitable to produce crude oil via its "de-oiling" (due to the higher oil content). In our case we study in the 3PCS type because most of the olive mills in South Europe use this type of pressing because it has the advantage to separate the solids from the liquid wastes.

According to the report of European Network the operation of the 3-phase decanter system for olives processing is given by the following scheme. (Fig.1)

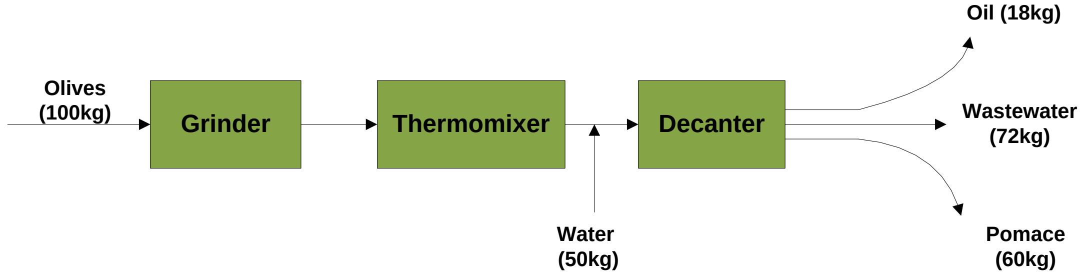

Figure 1: Processes in a 3-phase mill

3. Approach-case study of 3-phase mill

Figure 2 illustrates system analysis of the streams from olive oil mills in South Europe including the processes of treatment. The system comprises of 6 processes within the system border, the fluxes between these processes as well as the import and export fluxes to and from the system. The environmental compartment "groundwater or landfill disposal", is sunk for the residual fluxes. It is placed outside the system border and has not been investigated here.

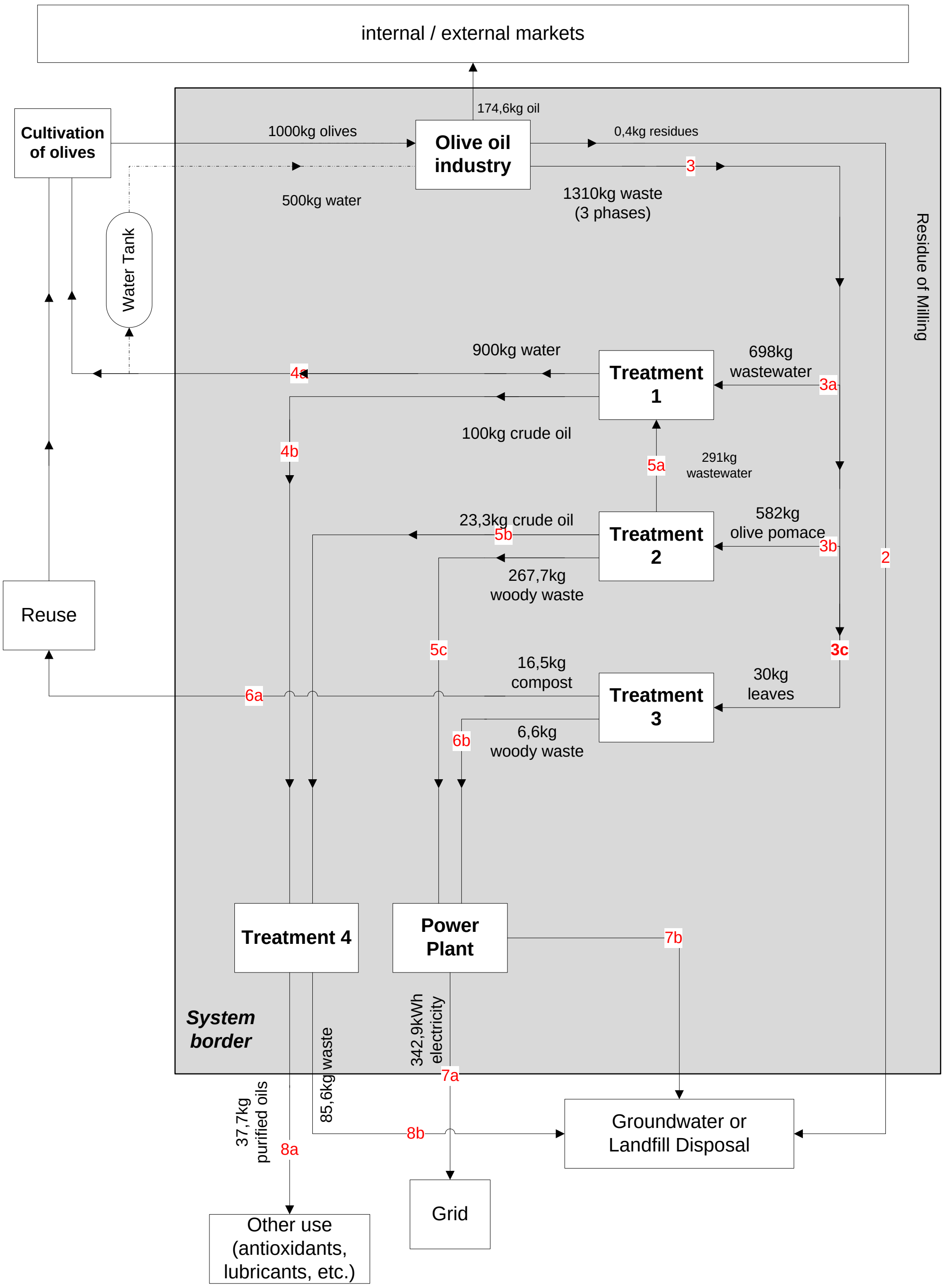

Figure 2: Reference Area and System Boarders for the material streams including mass fluxes in kg (fluxes are estimated with a 10-20% error margin)

There are several ways of determining mass and element fluxes. They can either be assessed by literature data (existing information), determined by field measurements, calculated by mass balances over a process or process chains, or through a combination of all these methods.

Table 2: Explication of the material flows & determination methods of mass and element fluxes

No.	Name of the material flow	Determination method
1	Raw materials (olives and leaves) which are used to olive oil mill	Available mills information and literature data (Azbar et al., 2004)
2	Residues from the oil production industry which are disposed on landfill sites	Available mills information
3	Basic waste streams from the production of olive oil (3a) wastewater (vegetation water), (3b) dry pomace (olive cake) and (3c) leaves	Available mills information
4	Wastewater treatment products: (4a) water for reuse and (4b) crude oil for other use (ie. polyphenols production)	Measurements and literature data (Azbar et al., 2004)
5	Pomace treatment products : (5a) wastewater for direct treatment, (5b) crude oil for other use (i.e. refining) and (5c) wood waste for combustion	Measurements and literature data (Konstantakatou,2010)
6	Pomace treatment products (6a) fertilizers (6b) wood waste for combustion	Measurements and literature data (Konstantakatou,2010)
7	Power generation (7a) electricity (7b) unused residues (remaining after the combustion)	Theoretical values (wood waste are combusted and landfilled) literature data [Intini et al.,2012),(Stamatakis)
8	Pharmaceutical processing - Refining (8a) antioxidants (polyphenols), lubricants (8b) unused residues (remaining after the processing)	Mass balance by assuming that 0,004% are disposed surface waters (Bensalah et al.,2004).

Wastewater

Wastewater has been the main concern of olive mill industry, law makers and public opinion because of its heavy environment impacts: it smells and seriously disturbs fresh surface and ground water (quality degradation), brings insects, disturbs plant grow and germination and disturbs soil structure decreasing porosity. EU covers 78% of the global olive oil production (Sturzenberger, 2007).

Every year almost 20 million tons of fresh water are consumed during the oil production period while 12 million tons of wastewater is produced. Mostly, this wastewater goes to the closest aquatic systems such as sea, rivers, lakes, etc. More specifically, 58% of the olive oil mills dispose of their wastewater into streams, which consequently in most of the cases ends up in larger water reservoirs, in the sea or in the soil (Bensalah et al., 2004).

Beneficial use of wastewater, such as by recycling the treated water and its end products, is anticipated. Despite there is no consensus on a successful and economic treatment method, storage and separation is the most common method for the wastewater treatment of olive oil production (Azbar et al., 2004).

Crude oil use

The natural antibacterial compounds in the olive are detected also in the wastewater together with other waste components after the olive oil production. Separation of the natural antioxidants from waste components and reuse of them as a raw material create high economic value for the industry (Takaç and Karakaya, 2009). Having in mind that the polyphenols concentration is ranging between 2-4 g/l and the market price for selling the final extract is estimated to be 0,4–1 €/g, it is concluded that it would be a valuable scenario (LIFE).

Solid waste (dry pomace)

Remnants of crushed olives partially drained from olive vegetation water, coming from 3PCS olive mills are clearly a byproduct obeying cumulatively to all requirements of the Article 5.1 Directive 2008/98/EC concerning wastes. The exhausted pomace, after oil extraction is still valuable for composting, animal feed or energy production (Cardoso et al., 2011).

Composting

Composting is a natural, biological and aerobic process during which, under specific conditions is realized partial decomposition of the organic matter, which is changed into a solid humid production, known as compost (Konstantakatou, 2010). The final product that is produced is stable and it can be used as organic fertilizer, without any adverse environmental effects. It is one option to treat organic solid waste prior to landfill (Michailides et al., 2011).

Leaves processing

About 3% of olives going to crush are olive leaves removed in the olive mill. Olive leaves are usually treated with natural bio-degradation (natural composting) or used for small ruminant's feed because its increasing quantities are starting to disturb olive mill owners. In Spain alone some 300 000 tons of leaves must be transported and disposed each year. Nowadays, leaves are treated with natural composting and the residues are used for energy production (Cardoso et al., 2011).

3. Results and Discussion

An "average" scale mill produces daily 13 tons of waste per day. This value is estimated with an error margin of about 10% and does not include the recycling for its own consumption. The data for the treatment of different types of waste are given in the literature. Figure 2 depicts the fluxes from 1ton olives. Around 69% is covered by reuse (water). About 20% is used for other use and the rest (11%) is either landfilled or transferred to the water. The raw materials for this oil industrial production are imported into the system and a small part of the products are exported out of the system. Therefore, the assessment and measurement procedure for the fluxes in our system has to be reviewed before drawing any conclusions. Below is given the calculation of the indicators which we take into account:

Indicators (South Europe, oil production sector)

- Input/output factor (oil production)

174.6 kg oil / 1000 kg olives = 17.5%

- Recycling quota for water

893 kg recycled water / (698+ 291) kg waste water = 90.3%

- Recycling quota for crude oil

(96+23.3) kg crude oil / (698 kg waste water + 582 kg olive pomace) = 9.3%

- Recycling quota for composting

16,5 kg compost / 30 kg leaves = 55%

- Recycling quota for woody waste (energy generation)

(267.7 + 6.6) kg woody waste / (582 kg pomace + 30 kg leaves) = 44.8%

Since the weather conditions are optimal for olive production, the demand for olive is high in order to meet the demand for olive oil. High amount of water is used for olive and olive oil production and important portion of this water is tried to be recycled. Also, crude oil as a by-product of oil production is derived for the other usages like lubricants, antioxidants, etc. In addition, there is an effort for recycling through composting and energy recovery. However, these processes are held separately and energy recovery is sustained by combustion of woody waste.

4. Conclusions

Olive mill wastes have a primary importance from the environmental point of view. These wastes can be considered as both a resource to be recovered and a waste to be treated. Many scientists work on efficient and cost-effective treatment alternatives. To achieve this goal, several alternatives and their combinations were tested including the chemical, mechanical, physical, biological and thermal methods.

From the perspective of sustainability, it is encouraging that municipalities, who can afford to discard materials, still want to participate in material recovery. It is a practical step that local authorities are willing to take in response to values rather than prices, a first hint of a social order beyond market necessity.

The wide range of international experience with recycling provides a good starting point for designing new programs for rapidly developing countries. Further innovations may be needed to create appropriate recycling programs for the South European cities and especially more subsidies for the collection systems design because they have shown that it is possible to recover significant quantities of materials at very low cost and of course to reduce the polluted load in the environment. (Ackerman, 2005)

Acknowledgements

The author thankfully acknowledge the Professor Gabriel Weber-Blaschke (TUM, Germany) for the information and clarifications provided to the study.

References

[1] Ackerman F., (2005). Material Flows for a Sustainable City: International Review for Environmental Strategies, Vol. 5, No. 2, pp. 499 – 510.

[2] Azbar N., Bayram A., Filibeli A., Muezzinoglu A., Sengul F., Ozer A., (2004): A Review of Waste Management Options in Olive Oil Production, Critical Reviews in Environmental Science and Technology, Volume 34, Number 3 / May-June 2004.

[3] Belevi H., (2002) Material flow analysis as a strategic planning tool for regional wastewater and solid waste management.

[4] Bensalah N., Bedoui A., Gadri A., (2004). Fenton treatment of olive oil mill wastewater--applicability of the method and parameters effects on the degradation process, Journal of Environmental Sciences, Vol. 16, No. 6, pp.942-044.

[5] Brunner P.H. and Rechberger H., (2005). Practical Handbook of Material Flow Analysis, Lewis Publishers.

[6] Cardoso Duarte J., Santori F., Ribeiro B., Augusto G., (2011). OLEICO Project: Olive Mill Wastes and the Sustainability of the Olive Oil Industry in Europe, Wastes: Solutions, Treatments and Opportunities 1st International Conference September 12th- 14th.

[7] Intini, F., Kühtz, S., Rospi G., (2012). Life cycle assessment (LCA) of an energy recovery plant in the olive oil industries, International Journal of Energy and Environment, Vol.3, Issue 4, pp.541-552.

[8] Intini, F., Kühtz, S., Rospi G., (2011). Energy Recovery of the Solid Waste of the Olive Oil Industries – LCA Analysis and Carbon Footprint Assessment, Journal of Sustainable Energy & Environment (2), 157–166.

[9] Konstantakatou P.P., (2010). Exploitation of Olive Mill Wastes, Master Thesis, Agricultural University of Athens, Greece.

[10] Lehmann S., (2010). Resource Recovery and Materials Flow in the City: Zero Waste and Sustainable Consumption as Paradigms in Urban Development, Vol. 11 - Issue 1 Fall 2010: Sustainable Development in the Urban Environment.

[11] LIFE, Project Number LIFE ENV/GR/000671 Name MINOS, Process development for an integrated olive oil mill waste management recovering natural antioxidants and producing organic fertilizer.

[12] Michailides M., Christou G., Tekerlekopoulou A.G., Akratos C.S., Vayenas D.V., (2011). Composting of Olive Mill Solid Wastes, 4th Environmental Conference of Macedonia, Greece, Proceedings of the 4th Environemntal Conference of Macedonia

[13] Stamatakis, G.; Energy and geo-environmental applications for Olive Mill Wastes: A review. Hellenic Journal of Geosciences, vol. 45, 269-282.

[14] Sturzenberger N., (2007). Olive Processing Waste Management: Summary, UC Davis Olive Oil, University of California, Davis

[15] Takaç S., Karakaya A., (2009) Recovery of Phenolic Antioxidants from Olive Mill Wastewater, Recent Patents on Chemical Engineering, Vol. 2, 230-237.